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## PATENT SPECIFICATION

### 1. TITLE OF INVENTION

Porous grinding stone having giant pores

### 2. CLAIMS

(1) In porous grinding stone having giant pores that have diameters 10 times or greater than grinding mineral,

porous grinding stone having giant pores which is characterized that coefficient of variation in diameter distribution of said giant pores is controlled to be 25 % or less.

(2) Porous grinding stone having giant pores of claim 1 wherein said grinding mineral is super grinding mineral.

(3) Porous grinding stone having giant pores of claim 1 or claim 2 wherein the binder for mutually binding said grinding mineral is inorganic binder.

(4) Porous grinding stone having giant pores which is described in one of claims 1 through 3 wherein said grinding mineral is CBN grinding mineral and said giant pores are formed by burning off resin balls in nitrogen atmosphere, which has been mixed with the grinding mineral along with inorganic binder.

(5) Porous grinding stone having giant pores which is described in one of claims 1 through 4 wherein said porous grinding stone is for honing or super finishing.

### 3. DETAILED DESCRIPTION OF THE INVENTION

Industrial application field

This invention concerns porous grinding stone that is provided with many giant pores having 10 times or greater diameters than grinding mineral.

Prior technologies

As described in Patent Publication Shou 39-20487, porous grinding stone having many giant pores that has relatively large diameter for the grinding mineral has been known. This type of grinding stones having artificially provided giant pores has been not only applied for petrified grinding stone but also applied for such as resinoid grinding stone and CBN grinding stone, and they have an advantage of less clogging to maintain cutting ability and having broad application range. Because cutting dust is captured

in said pores to appropriately prevent clogging, cutting ability is maintained, and on the other hand it is able to grind difficult-to-grind materials such as tool steel, light alloy and sintered alloy, which expands application range of the grinding stone.

Problem that the invention is to solve

However, because many giant pores are provided in its inside, previous porous stones as described above had a problem that stone wear amount against grinding amount is relatively large. The inventors have discovered a fact that the wear of stone against grinding amount is favorably improved if variation of diameter of pores that are provided inside of stone is controlled to be less, during several experiments based on above described background. This invention was done based on this knowledge.

Means to solve the problems

Namely, the summary of this invention is, in porous grinding stone having giant pores that have diameters 10 times or greater than grinding mineral, the coefficient of variation in diameter distribution of said giant pores is controlled to be 25 % or less.

Function and effect of this invention

By doing this, the grinding stone that is made to have the coefficient of variation of the giant pores to be 25 % or less is improved in wear amount of grinding stone to be almost half against grinding stones that are made in the same conditions except for the coefficient of variation of giant pores, although grinding amount is equal or better.

When super grinding mineral such as diamond or CBN (Cubic Crystalline Boron Nitride) is used as said grinding mineral, further favorable performance is obtained.

Also, when inorganic binder is used as the binder for mutually binding said grinding mineral, further favorable performance is obtained.

Further favorable property is obtained, when the CBN grinding mineral is used as said grinding mineral, and giant pores that are formed by burning off resin balls being mixed with the CBN grinding mineral along with inorganic binder in nitrogen atmosphere, as said giant pores.

Further, preferable property is obtained when said porous grinding stone is used as honing purpose or super finishing purpose.

Example

In the following, one example of this invention is described in detail based on drawings.

The CBN grinding stone 10 is in rectangular shape of 11 x 3.5 x 15 mm as shown in Figure 1, for example, and as shown in Figure 2 and Figure 3 it has CBN grinding mineral 12 with grit diameter 3 to 6  $\mu\text{m}$ , inorganic binder 14 that binds the CBN grinding mineral 12 mutually each other (petrified bond, for example it is boron-silica glass with melting point around 800 °C), and giant pores 16 having 10 times or more in diameter than the CBN grinding mineral 12. This grinding stone has a bulk density that makes mineral ratio 30 volumetric percent, binder ratio 20 volumetric percent and pore ratio 50 volumetric percent, in a state of after baking.

Said CBN grinding stone 10 is produced in well known process as the CBN stone making process, and the raw mix is added with pore forming particles having similar diameter with said giant pore 16, which are resin balls made of synthetic resin such as styrene, polyester, epoxy, for example, and uniformly mixed, during preparation stage of raw material. When this mixture is filled into a steel mold and press formed, then baked in nitrogen atmosphere of around 900 °C, said resin ball is burnt off during the baking process of the CBN grinding stone 10 and giant pores 16 having similar diameter with the resin balls are formed. And, resin balls in mean diameter 100  $\mu\text{m}$  is used which has a range of particle size distribution selected to be narrow, in said CBN grinding stone 10 of this example. The degree of expansion of the size distribution of the resin balls is defined to be 25 % or less when it is described in coefficient of variation  $C_v [= (\sigma/X_{av}) \times 100 \%$ , where  $\sigma$  is standard deviation,  $X_{av}$  is mathematical mean value of distribution]. Because the coefficient of variation of commercially sold resin balls is about 30 to 55 %, therefore, those selected from commercially sold resin balls by sifting are been used.

Figure 4 shows the results of comparison test over the control grinding stone, which is in the same production condition with said CBN grinding stone 10 except for the coefficient of variation  $C_v$  of the resin used ball being 30 %; said CBN grinding stone, namely sample No. 1 having 25 % of coefficient of variation  $C_v$ ; sample No. 2 having 20 % of coefficient of variation  $C_v$ ; and sample No. 3 having 15% of coefficient of variation  $C_v$ , in the grinding test condition I that is shown below.

[Grinding test condition I]

machining method:

ring end surface super finishing

grinding stone vibration frequency:

950 c.p.m.

grinding stone amplitude:	1.5 mm
material ground:	SUJ-2 (HRc62)
	50 dia. x T x 28
ground material surface velocity:	118 m/min.
machining time;	30 sec.

As it is apparent by above described Figure 4, not only the surface roughness is improved but also wear of grinding stone is favorably improved and durability is improved with the CBN grinding stone 10 of this example which has the coefficient of variation within 25 %. In further detail consideration, as shown in Figure 5, certain effect is recognized in wear rate (= grinding stone wear amount / unit grinding amount) with the sample 1 which has the coefficient of variation at 25 %, more significant effect in wear rate is recognized with the sample No. 2 which has the coefficient of variation at 20 %, and the most significant effect in wear rate is recognized with the sample No. 3 which has the coefficient of variation at 15 %.

As the reason why the grinding property is improved as described in above, it is considered that the diameter of the giant pores 16 becomes more uniform when the pore forming particles with less coefficient of variation Cv, and consistent size of cutting chips are obtained to enable to maintain stable grinding. On the contrary, when the coefficient of variation Cv is greater, it is considered that the pore forming particles become more prone to take a state of closest pack to cause regions of pore concentration which prevents uniformity.

In the following another example of this invention is described. Outer shape and pores of the petrified grinding stone 20 of this example are provided with white melted alumina grinding mineral (WA) of JIS standard number 2000 (particle diameter around 6.7  $\mu\text{m}$ ) 22, inorganic binder (petrified bond) 24 which bonds these white melted alumina particles 22, and giant pores 26 having more than 10 times of diameter of the white melted alumina particles 22, as same as CBN grinding stone 10 in above described example as shown in Figure 1 through Figure 3. This petrified grinding stone 20 has a bulk density that makes grinding mineral ratio 37 volumetric %, binder ratio 8.5 volumetric %, pore ratio 54.5 volumetric % (the pore ratio occupied by the resin balls among it is 12 volumetric %), in a condition after baking.

Said petrified grinding stone 20 is produced with a well known process as a process for producing

petrified grinding stone, however, pore forming particles having similar diameter with said giant pores 26 that are resin balls for example, are mixed in at preparation stage of raw materials. The giant pores 26 having similar diameter with the resin balls are formed by burning off the resin balls during the baking process of the petrified grinding stone 20. And resin balls having mean diameter 100  $\mu\text{m}$  and the coefficient of variation Cv 20 %, and the variation of diameter of the giant pores 26 is controlled to be small corresponding to the coefficient of variation Cv 20%.

Figure 6 shows the result of comparison test of petrified grinding stone 20 (sample No. 4) that has said coefficient of variation Cv at 20 % and the control grinding stone which has identical production condition with the petrified grinding stone 20 except for using resin balls with coefficient of variation Cv at 30 %, under the Grinding test condition II which is shown below.

[Grinding test condition II]

machining method:	ring end surface super finishing
grinding stone vibration frequency:	950 c.p.m.
grinding stone amplitude:	1.5 mm
material ground:	SUJ-2 (HRc62)
	50 dia. x T x 28
ground material rpm:	750 rpm
ground material surface velocity:	92 m/min.
machining time;	20 sec.

As it is obvious by the above described Figure 6, not only the roughness of finished surface is improved but also the wear of grinding stone for ground amount is reduced as much as 35 % and good durability is obtained, by the petrified grinding stone of this invention.

Further, other embodiment example of this invention is described. The petrified grinding stone of this example 30 has a long shape having convex curve shape grinding surface as shown in Figure 7 for example, and has green molten silicone carbide grinding mineral (SiC) 32 in JIS standard 320 grit (particle size of about 40.0  $\mu\text{m}$ , and as same as the CBN grinding stone 10 and petrified grinding stone 20 of above described examples that are shown in Figure 2 and Figure 3, it has inorganic binder (petrified bond) 34 that mutually bonds those green molten silicone carbide grinding mineral and giant

pores 36 having more than 10 times of pore size than said green molten silicone carbide grinding mineral 32. This petrified grinding stone 30 has a bulk density that makes grinding mineral ratio 43 volumetric percent, binder ratio 12 volumetric percent and pore ratio 45 volumetric percent (within this the pore ratio that resin balls occupy is 9 volumetric percent), in the condition after sintering.

Said petrified grinding stone 30 is produced with the same manufacturing process with above described petrified grinding stone 20 and the pore forming particles, resin balls for example, are similarly mixed at the preparation stage of raw material to form the giant pore 36. For this petrified grinding stone 30 resin balls with mean particle diameter 300  $\mu\text{m}$  with coefficient of variation  $D_v$  being 20 % are used and the diameter of the giant pore 36 is controlled to have small variation corresponding to the coefficient of variation  $C_v$  at 20 %.

Figure 8 shows the results of comparison test petrified grinding stone 30 (sample No. 5) having said coefficient of variation  $C_v$  at 20 %; the control grinding stone No. 1 which is in the same production condition with the petrified grinding stone 30 except for the coefficient of variation  $C_v$  of the resin used ball at 30 %; and further the control grinding stone No. 2 which has almost identical with the control grinding stone No. 1 as mineral ration 47 %, binder 9%, pore ratio 44 % but the pore forming particles are not mixed in production process, namely giant pores are not formed, in the grinding test condition III that is shown below.

[Grinding test condition II\*]

machining method:	horning
material ground:	FC23
grinding stone speed:	22.1 m/min
ground material speed:	22.3 m/min
grounding pressure:	6 kg/cm <sup>2</sup>
machining time;	60 sec.

*\*Translator's note: This "II" shall be a mistake of "III".*

As it is obvious by the above described Figure 8, not only finished surface roughness is improved by the petrified grinding stone 30 of this invention, but also wear amount of the grinding stone is reduced as much as 45 % against the control grinding stone No. 1 which has 30 % of the coefficient of variation  $C_v$

and 75 % against the control grinding stone No. 2 which is not formed with the giant pores, and favorable durability is obtained.

One embodiment example of this invention is explained in the above using a drawing, however, this invention is applied in other forms too.

For example, explanations were made on rectangular shape super finishing stone and long shape honing stone having convex curved polishing surface in above examples, however, it may be circular grinding stone, other kind of grinding mineral such as diamond may be used, and multiple kinds of grinding minerals may be used in a mixture.

Further, it is explained on CBN grinding stone 10 and petrified grinding stone 20 and 30 which use inorganic binder 14, 24 and 34, however, this invention may be applicable even it is so called resinoid grinding stone that uses organic binder in place of said inorganic binder 14, 24 and 34. In this case, pore forming particles that burns off at relatively low baking temperature of the resinoid grinding stone, naphthalene for example, is used.

Further, although pore forming particles that will be burned off in baking process are used in the CBN grinding stone 10 and petrified grinding stones 20 and 30 of above described embodiment examples, pore forming particles that will not burn off such as alumina balloon having giant pore inside of it may be used.

Further, above described is only one example of this invention and this invention may be applied with various modifications within a range that does not leave its original thought.

#### 4. Brief explanation of drawings

Figure 1 is an oblique view drawing that shows outer shape of the grinding stone of one Example of this invention. Figure 2 is a cross sectional view drawing that shows cross section of the Example in Figure 1, and Figure 3 is a drawing of enlarged major part of Figure 1. Figure 4 is a table that shows performance test result of the grinding stone of the Examples in Figure 1. Figure 5 is a graph that shows wear rate of the grinding stone of the Examples in Figure 1. Figure 6 is a table of other Example of this invention corresponding Figure 4. Figure 7 is a drawing of other Example of this invention corresponding Figure 1. Figure 8 is a table of the Example in Figure 7 corresponding Figure 4.



- 10: CBN grinding stone
- 12: CBN grinding mineral
- 16, 26, 36: giant pore
- 20: petrified grinding stone
- 22: white molten alumina grinding mineral
- 30: petrified grinding stone
- 32: green molten silicone carbide grinding mineral

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Figure 1

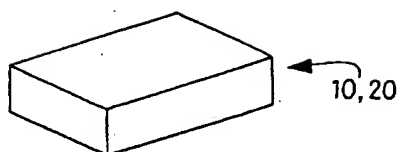


Figure 2

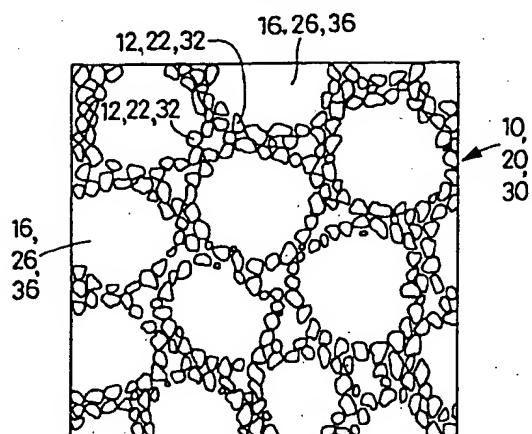


Figure 3

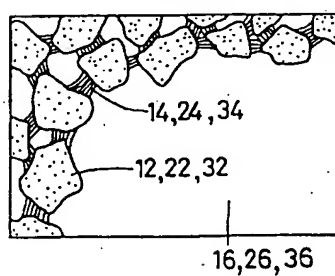


Figure 4

	grinding amount ( $\mu\text{m}$ )	grinding stone wear amount ( $\mu\text{m}$ )	finished surface roughness ( $\mu\text{m Rmax}$ )
control grinding stone	6	1.0	0.30
sample No. 1 Cv = 25 %	6.5	1.0	0.28
sample No. 2 Cv = 20 %	7.0	0.7	0.25

sample No. 3 Cv = 15 %	8.0	0.5	0.25
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Figure 5

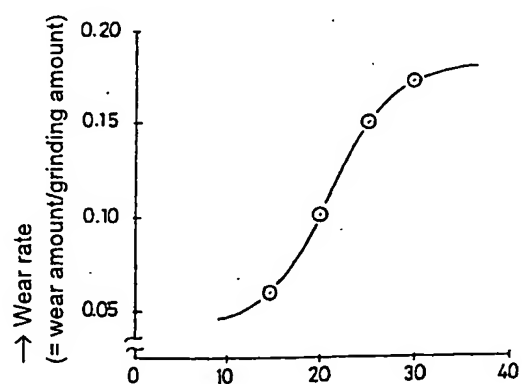


Figure 6

	grinding amount (μm)	grinding stone wear amount (μm)	finished surface roughness (μm Rmax)
control grinding stone	9	75	0.27
sample No. 4 Cv = 20 %	11	60	0.25

Figure 7

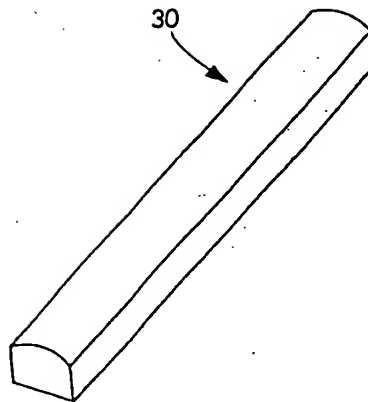


Figure 8

	grinding amount ( $\mu\text{m}$ )	grinding stone wear amount ( $\mu\text{m}$ )	finished surface roughness ( $\mu\text{m Rz}$ )
control grinding stone No. 1	50	500	4.5
control grinding stone No. 2	55	250	4.5
sample No. 5 Cv = 20 %	60	150	4.3

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